

Using i-Tree Hydro to Model Green Infrastructure

Dr. Ted Endreny, P.H., P.E., Tom Taggart, & Emily Stephan

From: SUNY ESF - Engineering - www.esf.edu/ere

Partners: USDA Forest Service & Davey Tree Expert Co.

For: VT DEC Watershed Management Division,

Green Infrastructure







Overview of Webinar



- Overview of i-Tree Hydro
- Green Infrastructure Simulations
 - -Watershed Simulation
 - Urban Simulation
 - Single Tree Simulation
- Ongoing Model Development



Overview of Webinar

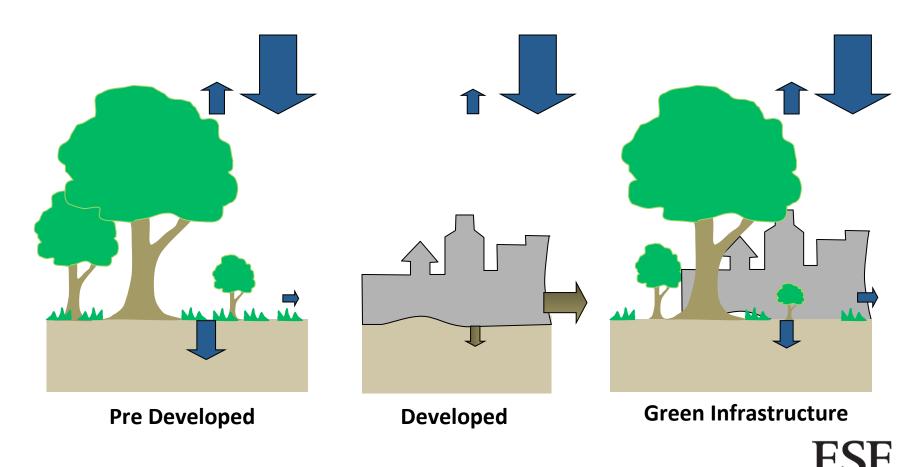


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i-Tree Hydro: Urban Forest Hydrology



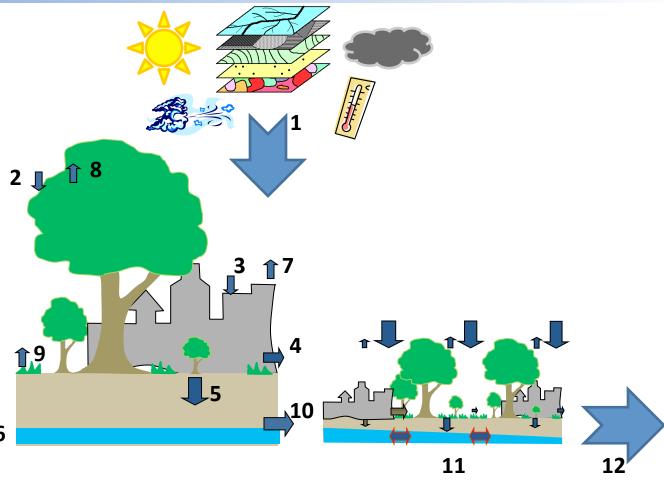


i-Tree Hydro: Inputs, Processes, & Outputs



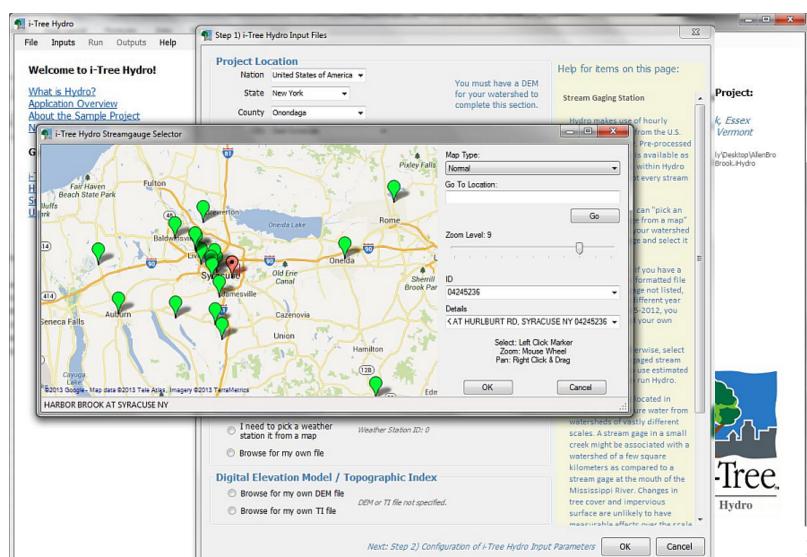


- 2 Canopy Interception
- 3 Depression Storage
- 4 Surface Runoff
- 5 Infiltration
- 6 Soil Moisture
- 7 Surface Evaporation
- 8 Tree Evaporation
- 9 Evapotranspiration
- 10 Subsurface Runoff
- 11 Spatial Distribution
- 12 Outputs

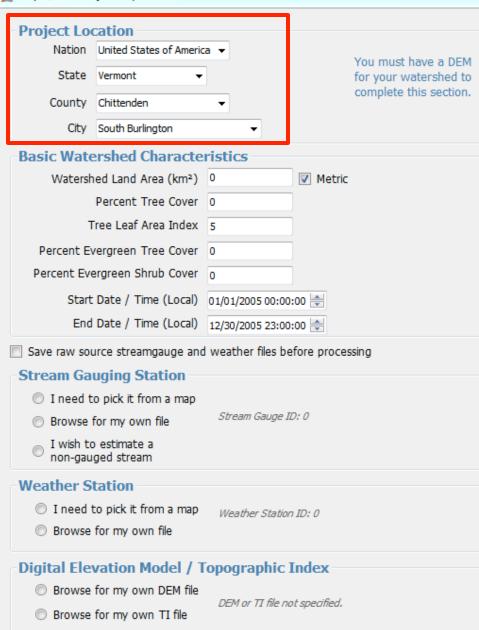


i-Tree Hydro: New model interface









Help for items on this page:

Watershed Land Area

Simply put, this is the entire area of the watershed you have chosen to model. Please make sure you have marked whether the data have been entered as metric or US units, as this will be critical to the modeling process. ideal source of this value would be from the watershed you built in your GIS system as i-Tree Hydro uses the actual watershed DEM in its calculations.

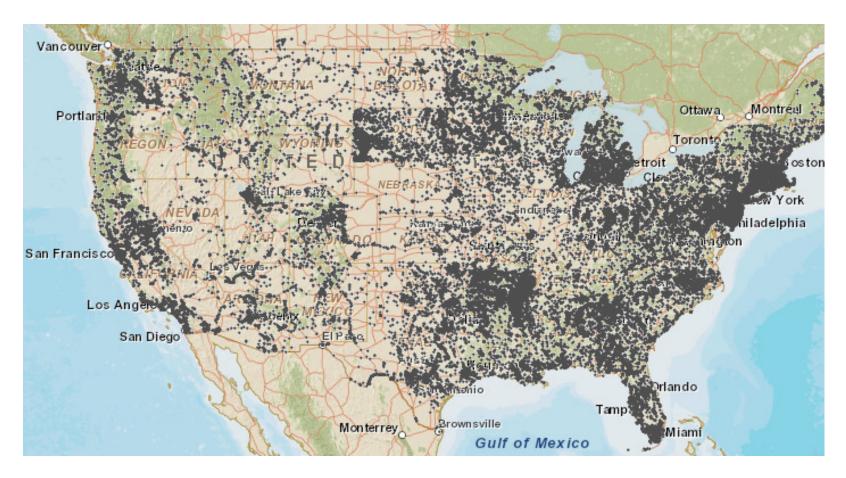
units: square kilometers / square miles





i-Tree Hydro: Project Location







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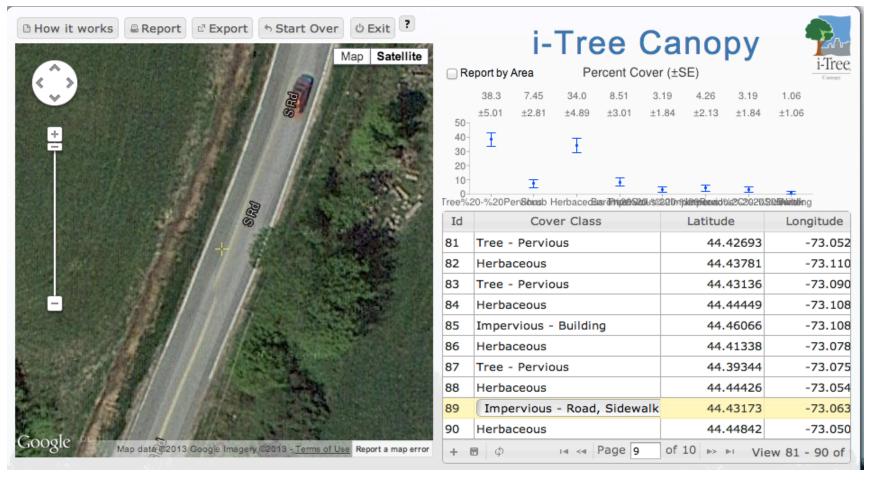
units: square kilometers / square miles





i-Tree Hydro: Land Cover Data (via i-Tree Canopy)







	, ,			
Project Lo	cation			
Nation		a ▼		
State	Vermont ▼			You must have a DEM for your watershed to
County	Chittenden	·		complete this section.
City	South Burlington	-		
Basic Wate	ershed Characte	ristics		
Watersh	ned Land Area (km²)	0	✓ Metric	
	Percent Tree Cover	0		
Т	Tree Leaf Area Index	5		
Percent E	vergreen Tree Cover	0		
Percent Eve	ergreen Shrub Cover	0		
Start	Date / Time (Local)	01/01/2005 00:00:0	0 🖨	
End	Date / Time (Local)	12/30/2005 23:00:0	0 🚔	
Save raw sou	urce streamgauge and	d weather files befo	ore proces	sing
Stream Ga	uging Station—			
	o pick it from a map	Character TD		
	for my own file	Stream Gauge ID:	U	
⊚ I wish to non-gau	o estimate a ged stream			
-Weather S	tation			
	to pick it from a map	Weather Station 1	D: 0	
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Digital Ele	vation Model / 1	opographic Ir	ndex	
_	for my own DEM file			
Browse	for my own TI file	DEM or TI file not	specified.	

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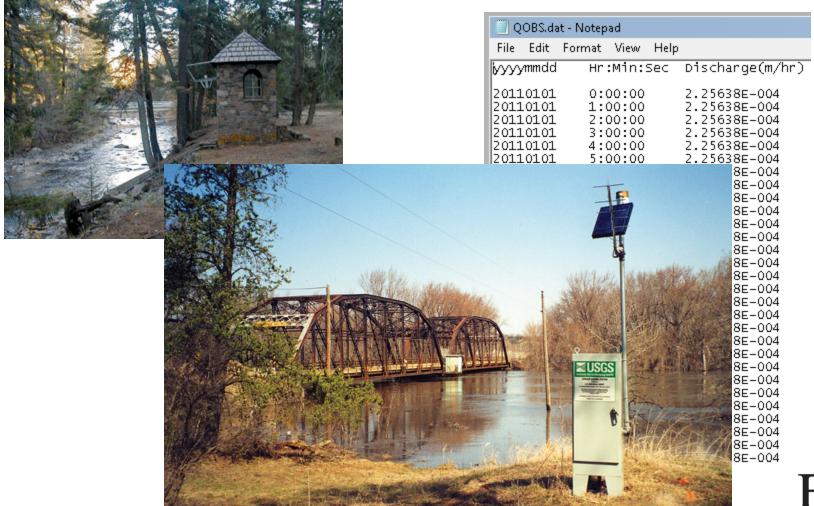
units: square kilometers / square miles





i-Tree Hydro: Stream Data option (loaded 2005-12) i-Tree







i-Tree Hydro: Weather Data (loaded 2005-12)





File Edit For	mat View Help						
yyyymmdd	Hr:Min:Sec	Tair(F)	Tdew(F)	NetRad(W/m^2)	WndSpd(m/s)	Precip(m/hr)	Snow(m/hr)
20110101	00:00:00	42.70000000	34.90000000	0.00000000	3.44210997	0.00000000	0.00000000
20110101	01:00:00	40.00000000	34.00000000	0.00000000	2.23513634	0.00000000	0.00000000
20110101 20110101	02:00:00 03:00:00	42.10000000 42.90000000	34.10000000 35.00000000	0.00000000	3.48681270 2.68216361	0.00000000	0.00000000
20110101	04:00:00	42.90000000	35.00000000	0.00000000	2.68216361	0.00000000	0.00000000
20110101	05:00:00	36.85000000	36.00000000	0.00000000	0.00000000	0.0000000	0.00000000
20110101	06:00:00	36.76000000	36.00000000	0.00000000	1.01922217	0.00023400	0.00000000
20110101	07:00:00	36.00000000	36.00000000	0.00000000	1.34108181	0.00000000	0.00000000
20110101	08:00:00	35.31578947	35.31578947	12.50021015	0.00000000	0.00000000	0.00000000
20110101	09:00:00	36.00000000	36.00000000	53.31007742	0.44702727	0.00000000	0.00000000
20110101	10:00:00	37.00000000	37.00000000	88.96392811	0.00000000	0.00000000	0.00000000
20110101	11:00:00	47.00000000	41.00000000	180.3095209	2.77156907	0.00000000	0.00000000
20110101	12:00:00	47.20000000	41.10000000	382.4534808	3.48681270	0.00000000	0.00000000
20110101	13:00:00	49.00000000	42.00000000	174.0454807	2.68216361	0.00000000	0.02540000
20110101	14:00:00	49.90000000	42.90000000	131.4296478	3.17389361	0.00000000	0.00000000
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20110101	16:00:00	49.00000000	42.00000000	27.88483690	4.91729996	0.00000000	0.00000000
20110101	17:00:00	46.00000000	41.90000000	0.00000000	3.57621815	0.00000000	0.00000000
20110101	18:00:00	46.30000000	41.10000000	0.00000000	3.63582179	0.00000000	0.00000000
20110101 20110101	19:00:00	49.00000000	42.00000000	0.00000000	3.12919088	0.00000000	0.02540000
20110101	20:00:00	50.00000000	40.90000000	0.00000000	3.71032633 5.05140814	0.00000000	0.00000000
20110101	21:00:00 22:00:00	50.00000000	40.00000000	0.00000000	6.25838176	0.00000000	0.00000000
20110101	23:00:00	49.00000000	39.00000000	0.00000000	6.79481448	0.00000000	0.00000000
20110101	00:00:00	48.90000000	39.10000000	0.00000000	7.42065266	0.00000000	0.02540000
20110102	01:00:00	48.00000000	40.00000000	0.00000000	5.81135449	0.00000000	0.02540000



Project Location Nation United States of America ▼ State Vermont ▼ You must have a DEM for your watershed to
Nation United States of America ▼ You must have a DEM
County Chittenden ▼ complete this section.
City South Burlington ▼
Basic Watershed Characteristics
Watershed Land Area (km²) Metric
Percent Tree Cover 0
Tree Leaf Area Index 5
Percent Evergreen Tree Cover 0
Percent Evergreen Shrub Cover 0
Start Date / Time (Local) 01/01/2005 00:00:00 😓
End Date / Time (Local) 12/30/2005 23:00:00 🚔
Save raw source streamgauge and weather files before processing
Stream Gauging Station
○ I need to pick it from a map
Browse for my own file Stream Gauge ID: 0
I wish to estimate a
onon-gauged stream
Weather Station
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Browse for my own file
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Browse for my own DEM file
DEM or TI file not specified.
Browse for my own TI file

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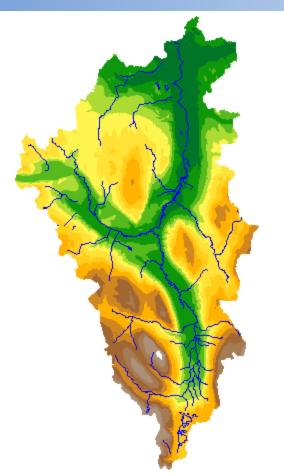
units: square kilometers / square miles



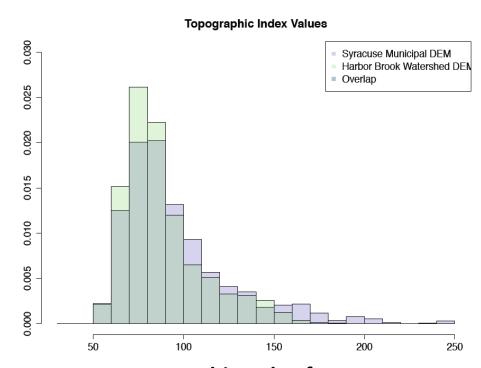


i-Tree Hydro: DEM vs Topographic Index Option





Digital Elevation Model (DEM)



Topographic Index from DEM

i-Tree Hydro: Green Infrastructure Simulation





Permeable Pavement



Sand Filter



Infiltration Trench



Rain Garden



Green Roof



Bio Swale



Rain Barrel



Urban Tree Cover



Retention / Detention



i-Tree Hydro: Land Cover Parameters



Land Cover Parameters Hyd	rological Parameters	Project Location	: Essex Junction, Vermont	
These parameter values describe		Attions		Help for items on this page:
Surface Cover Types	rne study area iand cover con	JUONS.		Impervious Cover
Tree Cover (%) Brub Cover (%) Herbaceous Cover (%) Water Cover (%) Impervious Cover (%) Soil Cover (%) Total Cover (%) (Should = 100)	3.0 40.7 0.7 7.3 0.3	 → Tree Leaf Area Index → Shrub Leaf Area Index → Herbaceous Leaf Area Index → Directily Connected Impervious Cover (%) 	5 2.2 1.6	This pertains to the areas UNDERNEATH the tree-covered portions of the watershed. Because not every watershed is completely covered with tree canopy, it is important to enter other cover types so that i-Tree Hydro can better model the area of interest. Impervious cover percentage
And it is important to know what Cover Types beneath		ereas of tree canopy.		would be the amount of watershed covered by roads, buildings, parking lots and other paved areas that prevent rainfall from naturally
Shrub Cover (%)	20.0			infiltrating into the soil.
Herbaceous Cover (%)	73.0			Total cover across all these
Soil Cover (%)	5.0			sub-types should add up to 100%. In other words, you are
Impervious Cover (%)	2.0			describing the total area underneath the tree cover
Total Cover (%) (Should = 100)	100.0			portion of the watershed as best as you can, without being under or over.
		Next+ Sten 3) i.Trae	Hydro Alternative Case	OK Cancel



i-Tree Hydro: Land Cover Parameters



and Cover Parameters Hyd	rological Parameters	Project Location.	: Essex Junction, Vermont	0.1.6.3
Surface Cover Types Tree Cover (%) as set on Raw Data Input form Shrub Cover (%) Herbaceous Cover (%) Water Cover (%)		Tree Leaf Area Index Shrub Leaf Area Index Herbaceous Leaf Area Index	5 2.2 1.6	Help for items on this page: Tree and Shrub Leaf Area Index Leaf Area Index (LAI) is the total leaf area divided by the total area of the study multiplied by the percent tree cover. I-Tree Eco users: Leaf area indexes can be calculated from
Impervious Cover (%) Soil Cover (%) Total Cover (%) (Should = 100) And it is important to know what	7.3 0.3 100.0	Directily Connected Impervious Cover (%)	2.0	Eco results for leaf area. These results are presented in units of m2/ha. To get LAI, divide by 10,000. A way to think about LAI is to imagine drawing a square on the ground under a tree canopy, with sides 1 meter in length.
Cover Types beneath			7	Standing in this 1-meter square area, looking up into the tree canopy, the LAI represents the
Shrub Cover (%) Herbaceous Cover (%)	73.0			surface area (1-sided) of the leaves present directly above
Soil Cover (%) Impervious Cover (%)	5.0			this 1 meter square area. Typical LAI values range from 1- 7, representing 1-7 square
Total Cover (%) (Should = 100)	100.0			meters of leaf area (1-sided) above this 1-meter square area.
				units: none

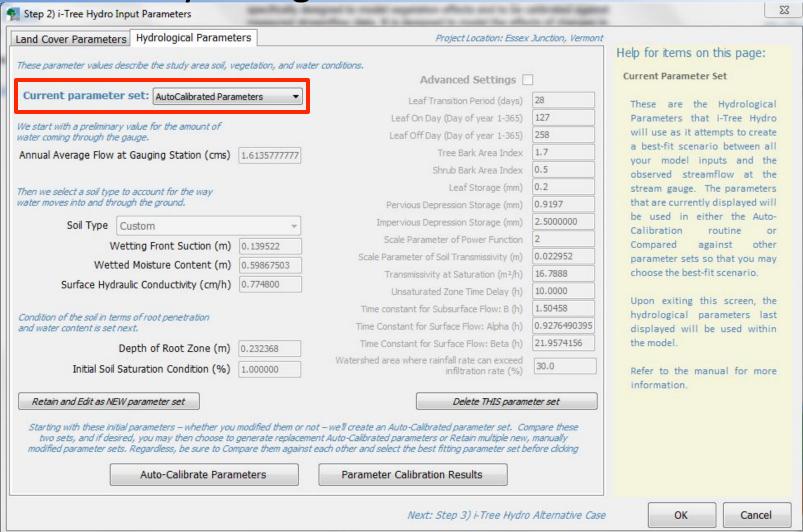


i-Tree Hydro: Land Cover Parameters

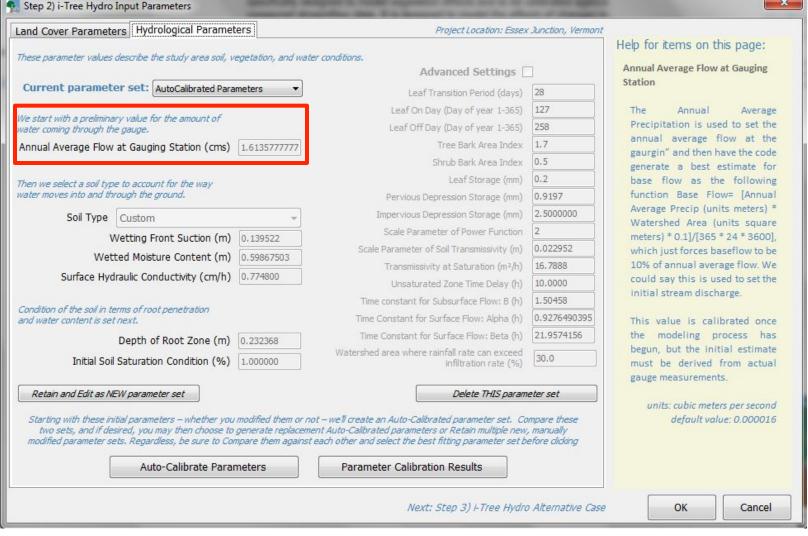


Land Cover Parameters Hyd	rological Parameters	Project Location	n: Essex Junction, Vermont	
Surface Cover Types Tree Cover (%) as set on Raw Shrub Cover (%) Herbaceous Cover (%)	3.0 40.7	Tree Leaf Area Index Shrub Leaf Area Index Herbaceous Leaf Area Index	5 2.2 1.6	Help for items on this page: Soil Cover This pertains to the areas UNDERNEATH the tree-covered portions of the watershed. not every watershed is completely covered with tree
Water Cover (%) Impervious Cover (%) Soil Cover (%) Total Cover (%) (Should = 100)	0.7 7.3 0.3 100.0	Directily Connected Impervious Cover (%)	2.0	canopy, it is important to enter other cover types so that i-Tree Hydro can better model the area of interest. Soil cover percentage would be the amount under tree canopy covered by bare soil or barren areas such as gravel pits or sand.
And it is important to know what Cover Types beneath Shrub Cover (%) Herbaceous Cover (%)	The second secon	th areas of tree canopy.		cover across all these sub-types should add up to 100%. In other words, you are describing the entire watershed as best as you can, without over or under estimating.
Soil Cover (%) Impervious Cover (%) Total Cover (%) (Should = 100)	5.0 2.0 100.0			units: percent
		Next: Step 3) i-Tre	e Hydro Alternative Case	OK Cancel



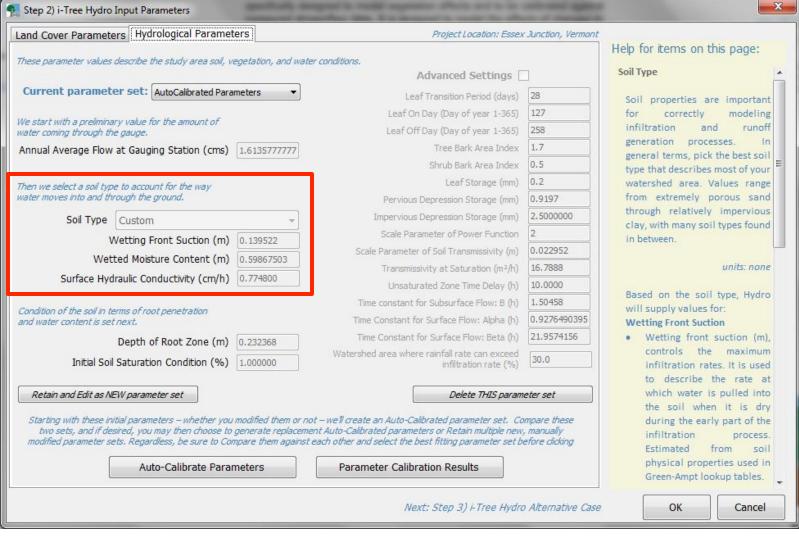






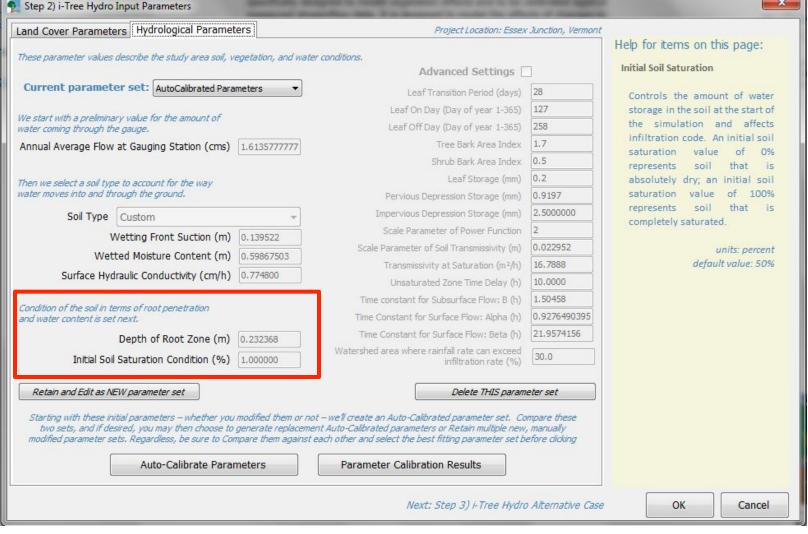






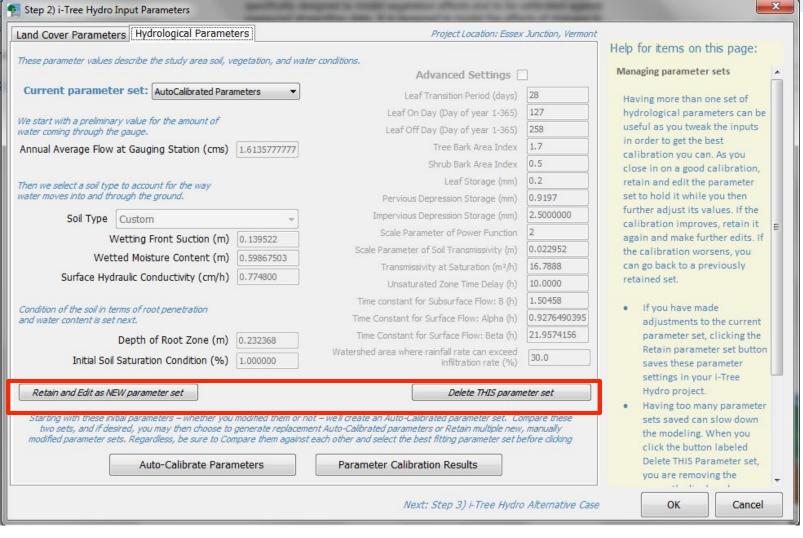






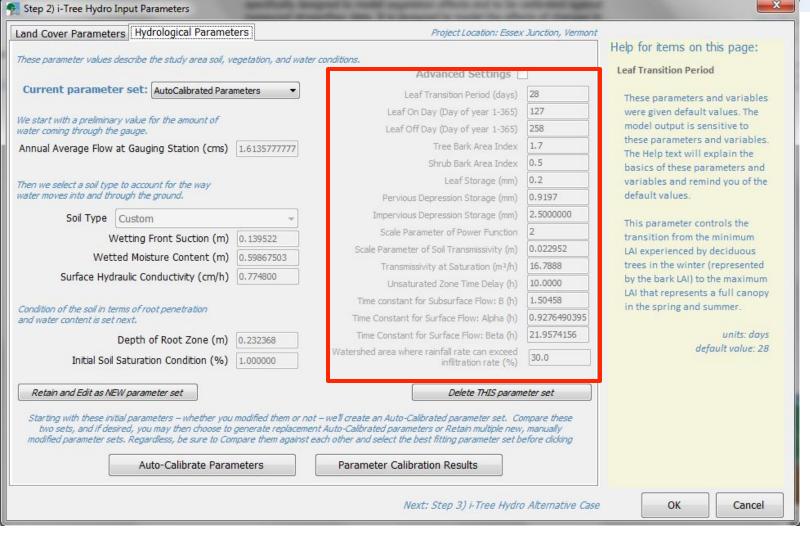






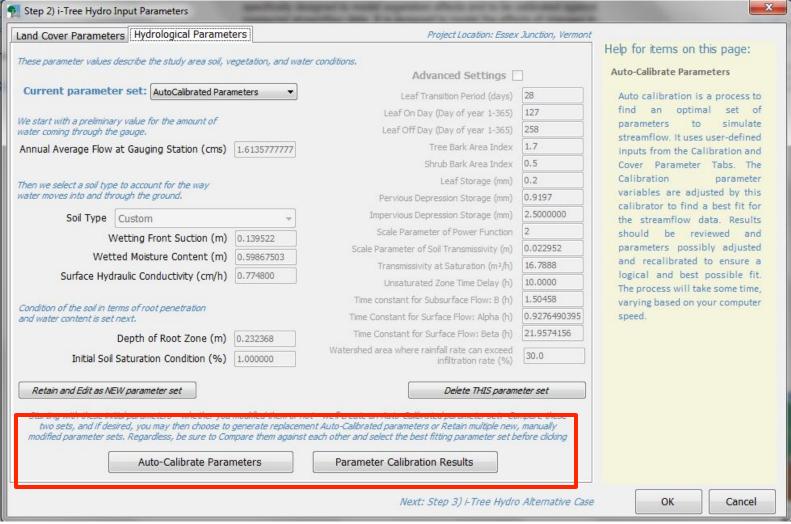
















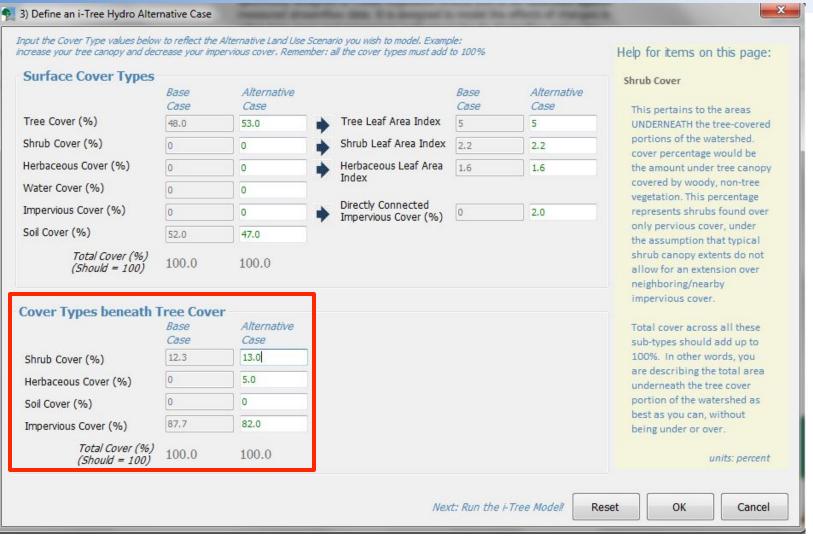
i-Tree Hydro: Alternative Case



Surface Cover Types			1				Percent Tree Cover
	Base Case	Alternative Case			Base Case	Alternative Case	How much of your watershed
ree Cover (%)	48.0	53.0	•	Tree Leaf Area Index	5	5	area is covered by tree
hrub Cover (%)	0	0	•	Shrub Leaf Area Index	2.2	2.2	canopy? Here you would enter this percentage. This
erbaceous Cover (%)	0	0	•	Herbaceous Leaf Area Index	1.6	1.6	percentage represents tree
/ater Cover (%)	0	0		Index			canopy found over both pervious and impervious
npervious Cover (%)	0	0	•	Directly Connected Impervious Cover (%)	0	2.0	cover. For example, trees
oil Cover (%)	52.0	47.0	ĺ				planted in a parking lot, where the majority of the
Total Cover (%) (Should = 100)	100.0	100.0					canopy might be over impervious asphalt, and trees planted in parks, where the
way Tymas banaath I	Two Cour						canopy is over pervious soil/grass, are both included
over Types beneath 1	Base Case	Alternative Case					in this percentage. This percentage could come from
hrub Cover (%)	12.3	13.0					data sources you have already compiled or you
erbaceous Cover (%)	0	5.0					could make use of other i-Tree
oil Cover (%)	0	0					tools, such as i-Tree Canopy (<www.itreetools.org canopy=""></www.itreetools.org>
	87.7	82.0), to create a statistical
mpervious Cover (%)							estimate of cover.



Alternative Case





i-Tree Hydro: Alternative Case



crease your tree canopy and dec	rease your imp	ervious cover, Remem	r: all the cover types must add	to 100%		Help for items on this pag
Surface Cover Types					3281 301	Tree and Shrub Leaf Area Inde
	Base Case	Alternative Case		Base Case	Alternative Case	Leaf Area Index (LAI) is the
Tree Cover (%)	48.0	53.0	Tree Leaf Area Index	5	5	total leaf area divided by th
Shrub Cover (%)	0	0	Shrub Leaf Area Index	2.2	2.2	total area of the study multiplied by the percent tre
Herbaceous Cover (%)	0	0	Herbaceous Leaf Area	1.6	1.6	cover.
Vater Cover (%)	0	0	Index			I-Tree Eco users: Leaf area indexes can be calculated
(mpervious Cover (%)	0	0	Directly Connected Impervious Cover (%)	0	2.0	from Eco results for leaf are
Soil Cover (%)	52.0	47.0	Impervious cover (70)			These results are presented units of m2/ha. To get LAI,
Total Cover (%) (Should = 100)	100.0	100.0				divide by 10,000. A way to think about LAI is t
Cover Types beneath 1	Fron Cour					imagine drawing a square o the ground under a tree
over Types beneath i	Base Case	Alternative Case				canopy, with sides 1 meter i length. Standing in this 1-
Shrub Cover (%)	12.3	13.0				meter square area, looking into the tree canopy, the LAI
Herbaceous Cover (%)	0	5.0				represents the surface area
Soil Cover (%)	0	0				(1-sided) of the leaves prese directly above this 1 meter
Impervious Cover (%)	87.7	82.0				square area. Typical LAI
Total Cover (%) (Should = 100)	100.0	100.0				values range from 1-7, representing 1-7 square



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GI in Watershed Simulation: Allen Brook, Vermont





Alllen Brook Watershed 30m DEM 9.9 mi²

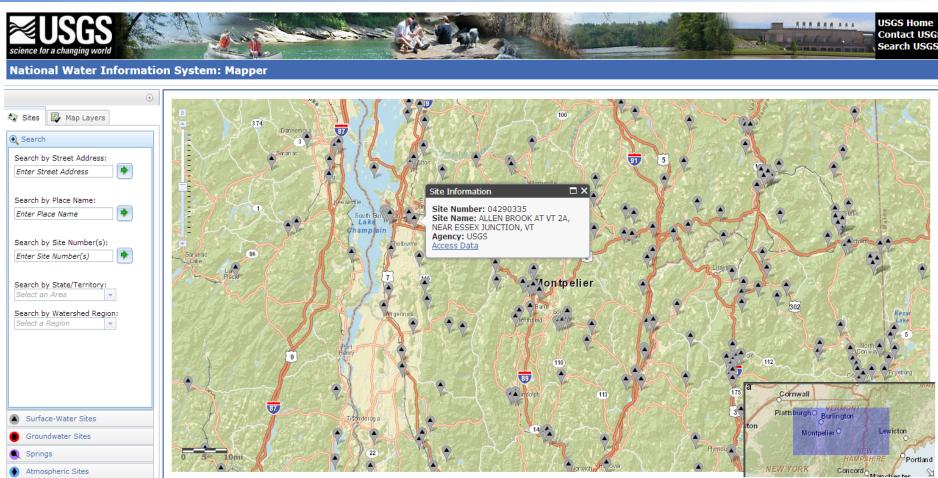


Tree Plantings 2005 Stormwater Impaired



GI in Watershed Simulation : Finding USGS gauge for calibration





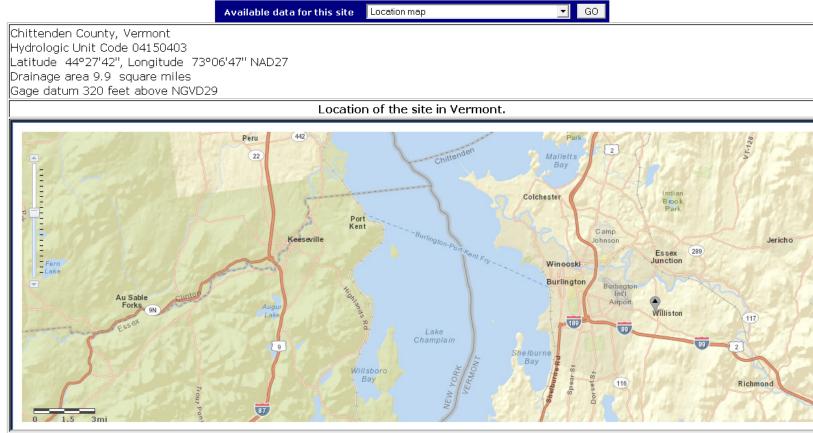


GI in Watershed Simulation: Locating county & town for gauge



Site Map for the Nation

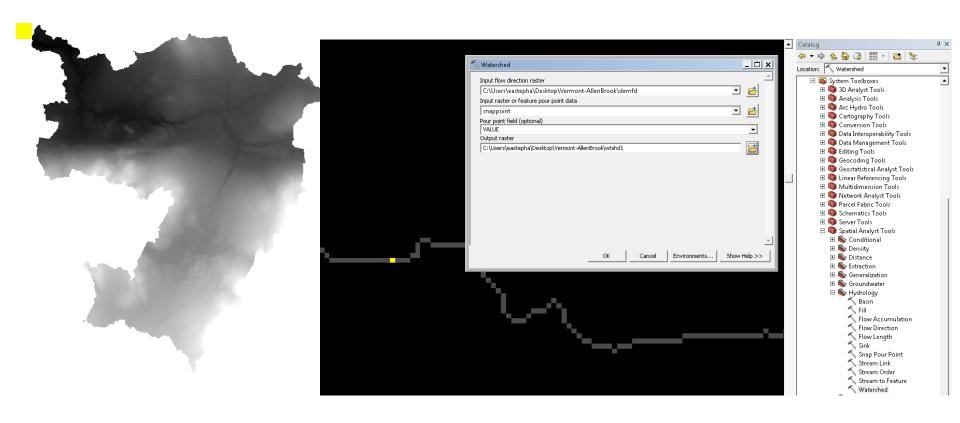
USGS 04290335 ALLEN BROOK AT VT 2A, NEAR ESSEX JUNCTION, VT





GI in Watershed Simulation: Delineating watershed in ArcGIS







GI in Watershed Simulation: Getting Land Cover w/ i-Tree Canopy







GI in Watershed Simulation: Calibrating of Hydrological Parameters i-Tree





GI in Watershed Simulation: Setting Green Infrastructure Scenarios





Permeable Pavement



Permeable Pavement



Permeable Pavement



Urban Tree Cover



Rain Garden



Rain Garden & Green Roof



Green Roof

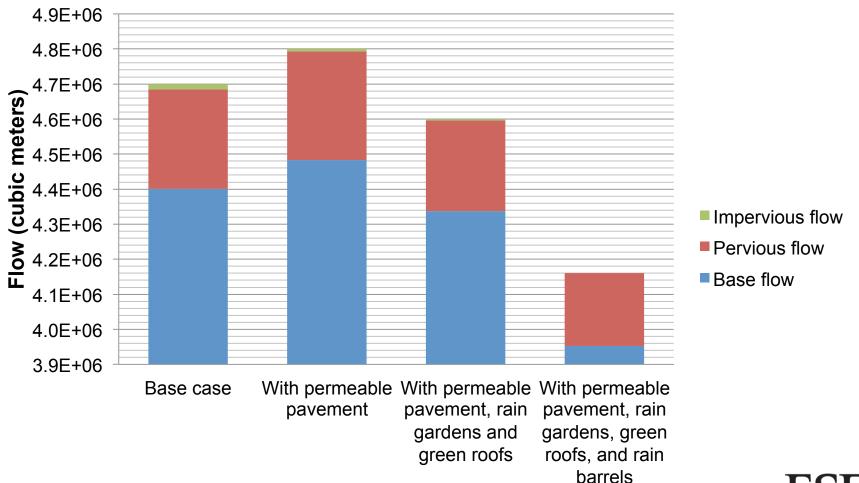


Rain Barrel



GI in Watershed Simulation: Base Case vs 3 GI Scenarios Total Flow for 2012, Allen Brook

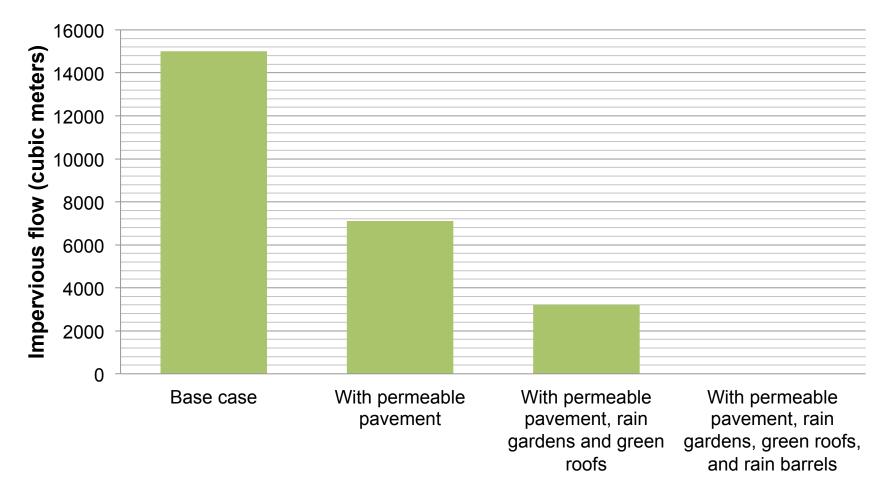






GI in Watershed Simulation: Base Case vs 3 GI Scenarios Impervious Cover Flow, 2012

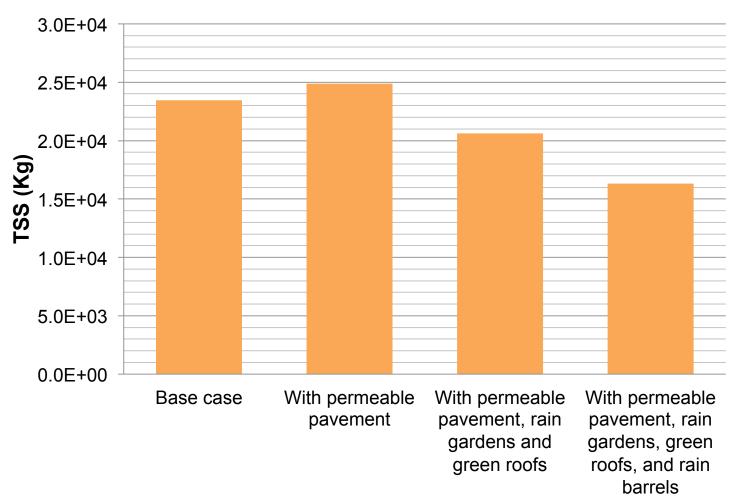






GI in Watershed Simulation: Base Case vs 3 GI Scenarios Total Suspended Solids, 2012







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GI in Urban Area Simulation: Burlington, Vermont





Burlington, VT Area 30m DEM into TI values 10.6 mi²

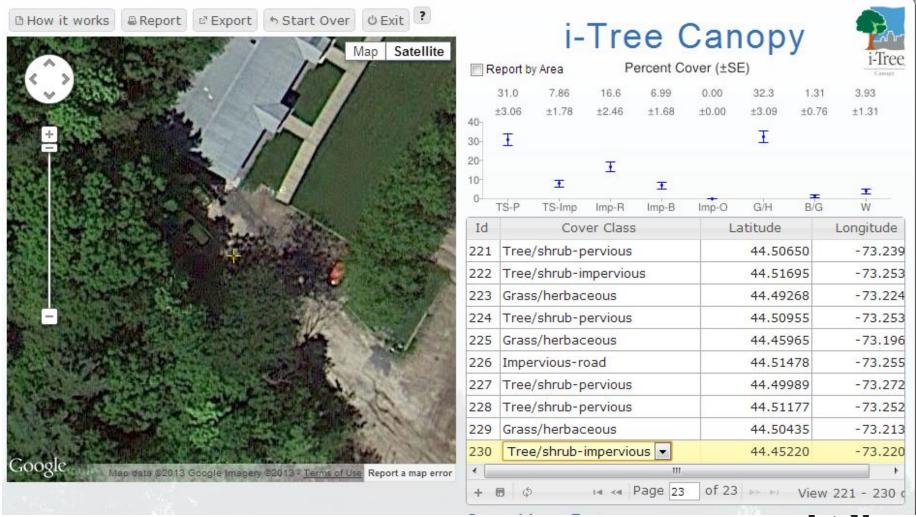


Downtown
GI Inspired Community



GI in Urban Area Simulation: Getting Land Cover w/ i-Tree Canopy

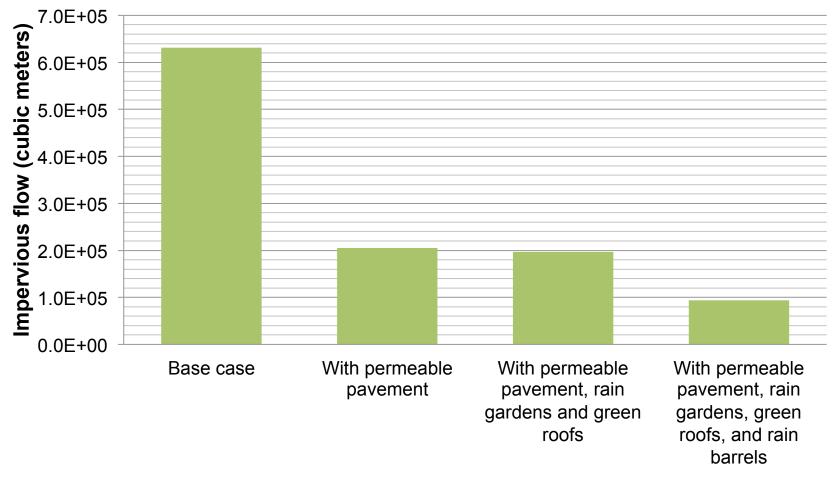






GI in Urban Area Simulation: Base Case vs 3 GI Scenarios Impervious Flow for 2012, Burlington



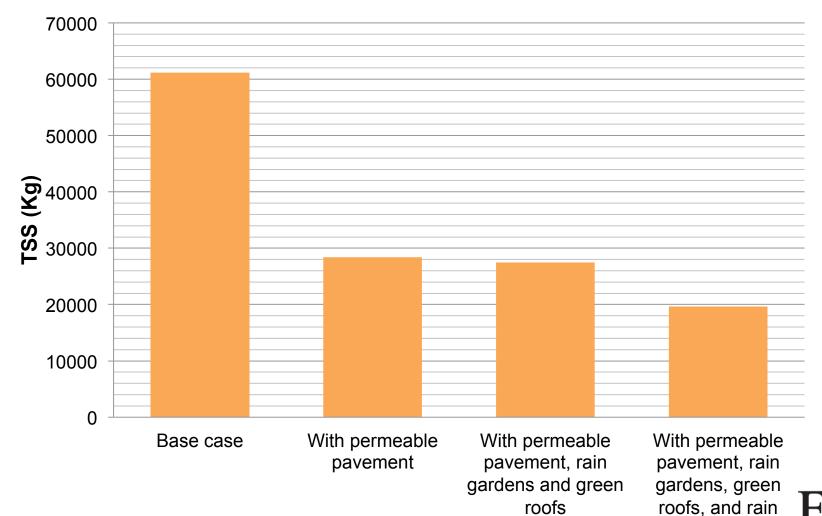




GI in Urban Area Simulation: Base Case vs 3 GI Scenarios Total Suspended Solids, 2012



barrels



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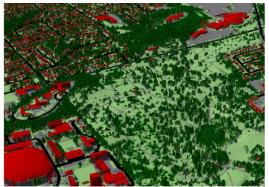
GI as Single Urban Tree / Save the Rain: Syracuse, New York











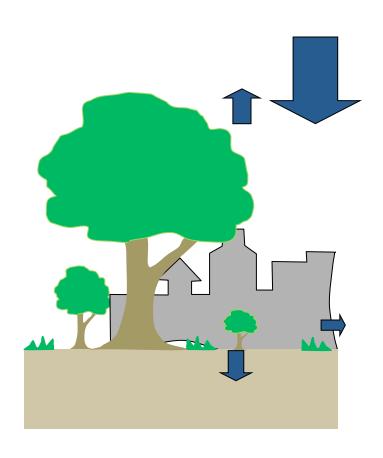
LiDAR Image of Tree Surface

Onondaga County & CH2M Hill Save the Rain Program
OnCenter Green Roof



GI as Single Urban Tree / Save the Rain: Single Tree Effects





Total Rainfall: 518 mm
Total Snow LE: 77 mm
Intercepted Rain: 70 mm
Intercepted Snow: 54 mm

Total Runoff: 145 mm



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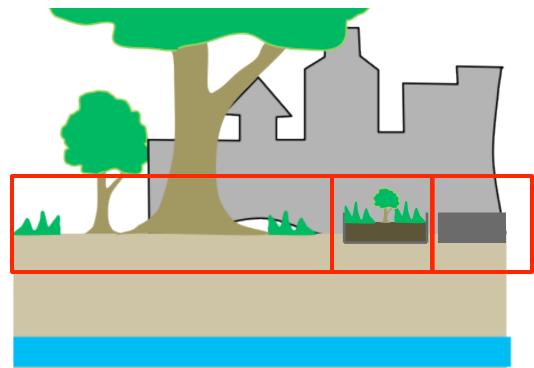


Ongoing Model Development: Semi-Distributed Green Infrastructure



- Extend current model for specific GI processes
 - Percentage of the watershed with GI

Land Cover Types
Pervious
Impervious
Green Infrastructure





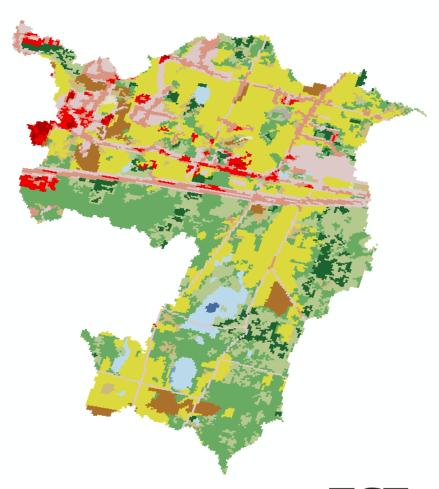
Ongoing Model Development



Distributed iTree Hydro

New Land Cover Data

GI Widgets

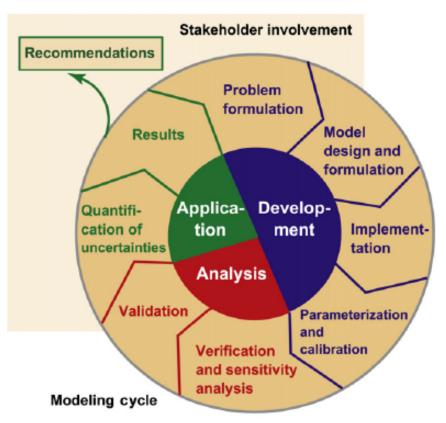




Ongoing Model Development: TRACE



<u>TRansparent And Comprehensive Ecological</u> (TRACE)



- 1. Model development
 - Problem formulation
 - Design and formulation
 - Model description
 - Parameterization
 - Calibration
- 2. Model testing and analysis
 - Verification
 - Sensitivity analysis
 - Validation
- 3. Model application
 - Results
 - Uncertainty analysis
 - Recommendation



The End



Your Questions & Our Gratitude!

Dr. Ted Endreny, P.H., P.E., Tom Taggart, & Emily Stephan

From: SUNY ESF - Engineering - www.esf.edu/ere

Partners: USDA Forest Service & Davey Tree Expert Co.

For: VT DEC Watershed Management Division,

Green Infrastructure





